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MECHANICAL DESTABILIZATION OF CREAM EMULSIONS

by

SURJIT SINGH KAMRA

A THESIS

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The Undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled

MECHANICAL DESTABILIZATION OF CREAM EMULSIONS

submitted by Surjit Singh Kamra in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The destabilized fat content of cream received by creameries, based on the examination of 110 shipments, ranged from 0 - 63% and 2 - 16% in the winter and summer seasons respectively and in the latter case it did not vary appreciably over a period of 5 weeks.

Cream churned by the conventional method had approximately 90% destabilized fat after 20 minutes. The processing of cream to mechanically destabilize the cream emulsion before churning reduced the churning time by 22 - 73%, when one destabilizing pump was used. The increased destabilization of cream through the use of two destabilizing pumps further reduced the churning times to the range of 40 to 89%, irrespective of whether cream was destabilized after cooling and holding it overnight or immediately after cooling. Churning cream in the presence of butter granules from a previous churning did not reduce the churning time. However, the working time for two churnings of butter worked together was the same as for one.

Contrary to expectations, mechanical destabilization of cream did not increase the fat loss in the buttermilk. Churning cream in the presence of the granules of a previous churning did, however, slightly increase the fat lost. The hardness of butter was not increased by mechanical destabilization of the cream.

The homogenization of high fat content cream increases the destabilization of the cream emulsion when the pressure, temperature and fat content were increased, but increases in temperature were not as effective in increasing the rate of destabilization of 76% fat cream, as it was with creams having 65 and 70% of fat. This finding

apparently results from the distortion of the fat globules reported to occur at fat contents above 74.04%.

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I. INTRODUCTION

Buttermaking involves the concentration of the fat phase of milk, first into cream (30 - 40% milkfat) by centrifugal separation and finally by churning into butter having a fat content of 80% or higher. Normally, in churning there is an incorporation of air causing foam, which together with agitation results in the profuse extension of the air plasma interface where the fat globules eventually collect. The agitation of churning gathers those globules into agglomerates held together by liquid fat squeezed out of globules, or released by globules that have become destabilized. Eventually this agglomeration of the fat globules causes the cream emulsion to break with the release from the cream serum or buttermilk of butter granules which are eventually converted into butter.

As a consequence of extensive investigations continuous methods of buttermaking were developed in Australia, Germany and the U.S.A. in the early 1940's. The principal advantage of these new methods of buttermaking is the mechanization of the process with a consequent reduction in manual labour. Inspite of a fairly rapid introduction of the continuous methods of buttermaking, the conventional method using stainless steel barrels will continue to be the principal buttermaking method for a considerable time especially in the smaller creameries that can not afford the rather large capital investment required to install the equipment for one of the continuous buttermaking methods.

The time required to convert cream into butter granules, usually 30 - 40 minutes and frequently considerably longer, is one of the principal criticisms of the conventional method of buttermaking. If this time could be considerably reduced, (it only requires a few seconds in the Fritz type continuous churn), the mechanization and consequently the efficiency of the conventional method could be greatly increased.

Sirik et al. (1953) developed a cream destabilizer resembling a centrifugal pump. In this device cream was destabilized due to mechanical action of the impeller and a reduction of 35 - 50% in churning time was achieved. But there has been no report of this method having been adopted on a commercial scale.

Weinreich (1965) reported on the development of a "Prechurn" by the Cherry - Burrell Corporation, Cedar Rapids, Iowa, U.S.A. The equipment consisted of a metallic cylinder with a number of close fitting beating blades revolving at 1,750 r.p.m. This prechurn was used in commercial scale experiments in an Iowa state creamery. Results of such experiments are not available in the literature and there is no report of this prechurn being used for commercial churning of cream.

The object of this research was to develop a method for mechanical destabilization of cream which could be employed with conventional churning to achieve a reduction in churning time. The prechurn developed by the Cherry - Burrell Corporation was too large to be used on a pilot plant scale. On the advice of the Cherry -

Burrell Corporation a high speed pump (3,650 r.p.m.) with a perforated impeller, such as used in the Gold'n Flow process of continuous buttermaking, was used to destabilize cream before churning. A higher degree of cream destabilization was achieved by incorporating air into cream and using two destabilizing pumps instead of one.

A part of the research project involved the measurement of the destabilization of high fat content cream caused by homogenization.

II. REVIEW OF LITERATURE

1. The Milk Fat Emulsion

Milk as it comes from the udder of the cow contains fat in the liquid form and it represents a typical oil-in-water emulsion. Because of the presence of surface forces the fat particles occur as globules floating in the milk plasma. Cream is obtained by centrifugal separation resulting in the concentration of fat globules. The fat in cream is still present in the oil-in-water type emulsion.

According to King (1955) the emulsion stability arises from the presence of a thin layer of a third component, the emulsifier on the surface of the dispersed particles. This layer forms an energy barrier at the globule surface preventing the aggregation which would otherwise follow collision between the globules. The energy barrier could be either mechanical or electrical. The mechanical energy barrier results from the existence of a semisolid membrane around the globules, while the electrical barrier is due to their like electric charges. In the commonest case the barrier is both mechanical and electrical. The chemical composition and the physical structure of a surface membrane determine its compactness and strength, which seem to be the decisive factors in the response of an emulsion to different treatments under different conditions.

The stability of the milk fat emulsion is also affected

by these stabilizing factors. Milk fat globules are surrounded by a membrane about 5 mμ thick (King 1955), the most important component being a complex of phospholipids and proteins and along with the negative charge on the fat globule which causes an electrical barrier, these factors maintain the stability of milk fat emulsion.

2. The Milk Fat Globule Membrane

Ascherson (1840) in his "haptagon membrane theory", advanced the concept of a membrane around the fat globule. Storch (1897), Voltz (1904), and Bauer (1911) examined the fat globule membrane under the microscope by using different washing and staining techniques. Schmid (1924) by the use of dark ground illumination, also indicated the presence around the fat gloubles in milk of a membrane which disappeared under the action of pepsin plus hydrochloric acid.

The morphology of the fat globule membrane has been studied by the application of electron microscopy. Schwarz (1947) observed the electron photomicrographs of the fat gloubles from unpasteurized 35 per cent cream, diluted 1,000 times with physiological saline. He reported that the fat globules were "surrounded by three layers: an inner thin, dark layer supposed to consist of proteins; a layer looking like a series of small beads, supposed to consist of phospholipids; and a broad diffuse layer supposed to be a slimy protein-like material carrying the Schardinger enzyme."

Voltz (1904) and Abderhalden and Voltz (1909) isolated

the proteins from the membrane material. In their opinion fat globule membranes consist, apart from casein, of some other proteins, or possibly exclusively of such proteins. Titus _et al._ (1928) reported that the product isolated was closely related to, if not identical with casein. On the other hand Storch (1897) reported that the proteinaceous substances obtained exhibited properties totally different from those of casein and lactalbumin. Palmer and Samulesson (1924), Hare _et al._ (1952), Herald and Brunner (1957) and Mulder and Menger (1958) suggested that the isolated proteins appeared to have unique amino acid composition and physical properties. Palmer and Lewis (1933) and Coulson and Jackson (1962) reported that the proteins isolated from the fat globule membrane differed immunologically from all but a minor protein component of skim milk. Ramachandran (1960) isolated a protein fraction of the fat globule membrane and by carrying out electrophoretic analysis, diffusion constant and molecular weight determinations, confirmed the earlier observations that the protein fraction was different from all the other known proteins of milk.

In addition to the presence of protein in the fat globule membrane, Palmer and Wiese (1933) reported the presence of phospholipids, the two probably forming a complex called lipo-protein. Jennes and Palmer (1945 a) gave the phospholipid:protein ratio in the membrane material as 1.8 - 2.4. According to Loewenstein and Gould (1954) the membrane material contained an average of 21.86 percent protein and 70.65 percent ether extractable material. The ether

extractable fraction contained an average of 12.10 percent phospholipids.

Hayashi and Smith (1965 a) separated water-soluble lipo-proteins particles accounting for 45% of the total weight of the membrane. Chemical analysis of these lipo-proteins showed that lipids and proteins were present in approximately equal amounts and that 76% of these lipids were phospholipids. It was further suggested that the membranes surrounding the fat globules consisted of two types of lipo-protein complexes, approximately equal in amounts and distinquishable on the basis of their solubility in water. The water soluble lipo-proteins are considered to be adsorbed on a water - insoluble matrix, composed of lipids and proteins bordering the triglyceride core of the fat globules. Richardson and Guss (1965) by the analysis of the centrifuged fractions of the fat globule membrane material from buttermilk of churned washed cream obtained two basic categories: a high density reddish brown fraction high in proteins and low in lipids, and a low density cream colored fraction low in proteins and high in lipids. The lipids of the high density fraction were higher in phospholipids and greater in total unsaturation and polyunsaturation than the low density fraction.

Palmer and Wiese (1933) reported the presence of high melting triglycerides. The origin and nature of high melting triglycerides was further investigated by Jennes and Palmer (1945 b). It was believed that the butter plasma contained more of the high

melting triglycerides because of the affinity between the molecules of the high melting triglycerides and the fatty acid chains of phospholipid material. On the other hand Vasic and deMan (1966) presented evidence that high melting triglycerides are in reality an artefact resulting from the crystallization of these glycerides in peripheral layers of these globules, just as solutions of milk fat in solvents will deposit crystals on the glass walls of a container.

Besides the proteins, phospholipids and triglycerides which are the major constituents of the fat globule membrane, the following authors: Davies (1933); Mulder and Koppejan (1953); Whitney (1958); Brunner (1962) and Richardson and Guse (1965) reported the presence of cholestrol, cholestryl esters and metals such as iron, copper, molybdenum and zinc as the minor constituents of the fat globule membrane. Rimpila and Palmer (1935); Polonovski et al. (1949); King (1955); Richardson and Guss (1965) and Hayashi and Smith (1965 b) reported the occurence of xanthine - aldehyde dehydrogenase, phosphatase and aldolase enzymes in the membrane. Xanthine oxidase and alkaline phosphatase have been found to be localised principally in the water - soluble portion of the lipoproteins of the fat globule membranes.

The milk fat globule membrane has been found to contain 15% of the total bound water in a whole milk of average fat and total solids content (Pyenson and Dahle, 1938). The phospholipid component of the membrane material posseses a high water - binding ability.

Extensive information is available on the chemical composition of the membranous material, comparatively little is known regarding its physical structure. The general concept of the fat globule surface was put forward by Rimpila and Palmer (1935) and was later considered in more detail by Bird _et al_. (1937). They suggested that protective materials do not form a continuous membrane at the globule surface but are held at force centres which are randomly distrubuted. Morton (1954) suggested that "the fat globule in milk is surrounded by a continuous protein membrane on to which microsomal particles may be adsorbed". Zittle _et al_.(1956) likened these microsomes to a parcel of enzymes connected together by phospholipids and nucleic acid.

King (1955) depicted the membrane structure as a surface layer of polar phospholipids and other less polar lipids; eg cholestrol, vitamin A, etc., which in association with high melting triglycerides extend into the peripheral area of the fat droplet. Attached to the polar heads of the phospholipids, he showed a closely oriented layer of protein that seemed to extend into the plasma. Hayashi and Smith (1965b)put forward a tentative model of the structure of the fat globule. They considered "the globule to be a triglyceride core surrounded by a membrane consisting of two types of lipid - protein complexes distinguishable on the basis of their solubility in water. The insoluble lipid - protein complex borders the triglyceride core and provides a structure matrix on

which the lipo-protein particles are adsorbed." The layer composed of water-insoluble complexes containing lipids and protein may have a structure as depicted by King (1955) rather than the continuous protein membrane suggested by Morton (1954). It was further suggested by Hayashi and Smith (1965 a,b) that the outer layer consisting of adsorbed particles may be as in Morton's model, but for the most part these particles are water-soluble lipo-proteins and are considered to be smaller than microsomes. According to Harwalkar and Brunner (1965) hydrophobic and covalent disulphide linkages are significant forces contributing to the micro-structure of the membrane complex. The protective materials are of two types:

a) A phospholipid-protein complex oriented at the fat side of the interface,

b) Surface active components of the milk plasma, casein being probably the most important among them, which are situated on the water side of the interface.

Thus though the chemical composition of the membrane has been established, it needs still more work to explain the physical arrangement of various constituents forming the milk fat globule membrane.

3. Factors Affecting the Stability of Milk Fat Emulsion

The emulsion stability of milk or cream is of great practical and theoretical significance. In some products or processes it is desirable to retain as far as possible the original fine dispersion of the fat; e.g. milk for liquid consumption

cream products, condensed and dried milk, etc., while in other circumstances it is desirable to aggregate the milk fat more or less completely as is done in butter making, manufacture of "ghee" (clarified butter fat), butter oil, dehydrated butter oil and the determination of butterfat in milk and dairy products.

The extent to which the fat globules may aggregate is closely related to the behaviour of the fat globule surface, e.g. its composition, physical state and structure, mechanical and electrical properties, surface energy relations, etc.. The fat membrane lipo-proteins are sensitive to the usual agents that tend to disorganize native proteins and are sensitized by agents promoting destruction of the lipid components. King (1955) classified the factors which may cause the destabilization of the milk fat emulsion as follows:

1. Mechanical factors, such as: agitation and homogenization.
2. Thermal factors, such as: freezing, heating and temperature treatment (heating, cooling and heating).
3. Factors of a physico-chemical and biological nature, such as: drying and action of reagents and microorganisms.

4. The Influence of Agitation

The effect of agitation on the behaviour of the fat globule and the formation of butter have been discussed by King (1951, 1952, 1953). King (1953) suggested that during agitation,

the milk fat globules undergo two kinds of physico-chemical change. They (the fat globules) may aggregate to form large units, initiating the first stage in butter granule formation, or the smaller globules with a diametre of 2-4 microns, may be broken up and dispersed as very small globules with a diameter of 0.5 - 1.0 microns. The type of the physical change will depend on the size of the fat globules, the temperature, and the extent of treatment. According to Dolby (1957) the number of small fat globules to be formed is dependent upon the pH of the agitated milk or cream. When the pH of the agitated milk or cream is 7.30 - 7.45, the small globules predominate. This indicates that high acidity encourages clumping or formation of large fat globules. Thurston et al.(1936) and Greenbank and Pallansch (1961) have suggested that the membrane phospholipids are displaced into the plasma portion of milk as a result of agitation. Agitation effects encountered during the separation of milk cause the release of membrane materials, which seem to be accentuated at 90°F or above. Additional losses are encountered when quantities of incorporated air are present in the milk to contribute to the destabilization of the fat emulsion. King (1953) suggested that on agitating the milk or cream a profuse extension of the air-plasma interface is induced due to the incorporation of air bubbles into the plasma, as well as due to the continual renewal of the milk or cream surface. As soon as a fat globule comes into contact with the air-plasma interface a part of the membrane is spread out there together with a part of the liquid

fat fraction. A belt of liquid fat remains attached to the fat globule, which also retains a part of its membrane. When the globules become crowded on the surface of the interface and come into contact with each other, this belt of liquid fat serves as a cement uniting them into clumps. The globules are linked together by capillary cohesion forces, through the layer of liquid fat. Another part of the spread-out liquid fat forms a layer only a few molecules thick on the bubble surface, interspersed with islets of microscopically visible fat. Such a fat layer on a bubble acts as a foam depressant, causing it to burst. The fat layer on the surface of the bubble is then dispersed as particles of colloidal size in the plasma, while the fat globules crowded on the bubble surface are thrown against other clumps. On repeated formation and destruction of air bubbles the clumps grow to butter granules, which may contain more than 80% of their fat in the form of globules.

The principle of agitation for destabilization of cream emulsion has been employed in continuous butter making. In the latter part of the 19th century "Johanasson's butter extractor" was developed in which beating blades rotating inside a cylinder at high speed separated the buttermilk and butter from the concentrated cream (Reported by Grotenfelt and Woll, 1905). At the same time DeLaval invented a butter separator which consisted of a cylinder with beating blades in which an axle, also with beating blades, rotated at the rate of 3,600 r.p.m. "Two methods, the Fritz and the Sen processes, involved the churning of cream of normal

composition using intense mechanical agitation" (McDowell 1953). In the Fritz process the cream is churned in a cylinderical tank, the axle of which is placed horizontally and which is open at one end. It has a stirring device with four metal beating blades fitted perpendicularly on the axle at a distance of approximately one mu from the inner wall of the cylinder.

In case of the Cherry - Burrell process of continuous buttermaking as reported by deMan and Wood (1958 a) cream having a butterfat content of 30 - 40% and a temperature of 50°F is propelled from the holding vats to the cream separator with a metering pump. The cream passes through a filter to remove any coarse particles, such as precipitated casein and then flows through the destabilization pump after the incorporation of air which enters through a special intake vent. The destabilizing pump is a beater or whipping mechanism containing perforated rotor blades travelling at 3,000 r.p.m. Contrary to the view put forward by King (1954) that the destabilization occurs in a peripheral layer of the pump, it was found by deMan and Wood (1958 a) that the beater blades rotated in the completely filled pump chamber.

The principle of mechanical agitation for continuous buttermaking has been applied in the development of a destabilizer to reduce the churning time in a conventional buttermaking process. Sirik et al. (1953) obtained a reduction of 35 - 50% in the churning time by using a cream destabilizer and a metal churn. The cream destabilizer consisted of a cylinder with a stirrer revolving at

2,800 r.p.m. This apparatus had an output of 1,000 litre/hour.

Weinreich (1965) of the Cherry - Burrell Corporation reported the development of a "prechurn" which consisted of a metallic cylinder with a number of beating blades revolving at 1,750 r.p.m. Air was incorporated in the cream to produce foam and at the outlet of the prechurn a product holdback valve subjected the cream in the prechurn to a pressure of 15 - 20p.s.i. The cream after passing through the prechurn had a whipped grainy appearance. With this unit, the churning time for cream or time from which the churn was turned on until it was ready to drain buttermilk, was as low as 5 minutes. The normal churning time for cream varies between' 30 - 45 minutes. The change in the cream emulsion brought about by working the cream in a destabilizer or prechurn was similar to the change in the process of churning. This explained the reduction in the churning time.

5. Homogenization

Although homogenization has been used to stabilize the fat emulsion in milk, some rather profound changes occur at the fat - plasma interface. Upon homogenization, the fat globules are broken into small globules with approximately a five fold increase in the surface area. The actual increase depends on the intensity of the homogenization. Jackson and Brunner (1960) have shown that the increased fat surface created by homogenization served as an absorbing site for casein complexed with a portion of the milk lipids and the normally occuring membrane materials, and whey

proteins of undetermined nature. Fox et al.(1960) and more recently, Greenbank and Pallansch (1961) have reported the formation of a high density, lipid-casein complex in homogenized milk. It was also shown by the later authors that homogenization at or below 2,000 p.s.i. causes a migration of phosphatides away from the fat globule surface, but at higher pressures the migration is reversed until at a pressure of 8,000 p.s.i., the amount of phosphatides associated with the fat phase is approximately equal to that in the untreated milk.

With an increase in the fat content, the emulsion stability in homogenized cream decreases, and at a fat content of about 80% a complete breaking of the emulsion takes place. This phenomenon serves as a basis for the creamery package manufacturing company method for continuous buttermaking, and can also be used for manufacturing pure butterfat (Wiechers and Goede, 1950). With higher fat content creams the tendency to demulsification grows, since the source of additional coating material, the milk plasma, becomes scarcer and the inadequately protected globules are more tightly compressed, and at about 80% fat a complete breakdown into fat and aqueous phase occurs.

6. <u>The Effect of Freezing</u>

Rochow and Mason (1936) reported the breaking of emulsions by freezing and ascribed it to the following causes in sequence:

1. Withdrawal of free and/or bound water from the films

between touching droplets, by crystallization as ice, or by concentrating of any solutes present.

2. Establishment of true contact between adjacent films of emulsifier, with loss of the orienting influence of water.

3. Diffusion of the emulsifier in the film away from these thick regions.

4. Decrease in film area and coalescence of droplets as soon as the thawing of the ice permits them to change shape.

Polonovski et al. (1949) stated that on freezing, the membrane protein is liberated from the lipo-protein linkage together with a part of the xanthine dehydrogenase, while another part of the enzyme remains attatched to the high melting fraction. The damage to globule membrane due to freezing was also confirmed by Cole et al. (1959). Favstova and Vladavets (1955) reported that the destabilization of cream in the absence of mechanical agitation is favoured by low temperature, $-10^{\circ}C$ and high fat content. At $100^{\circ}C$, a pronounced destabilization occurs only in samples with 90% fat, where as at $-10^{\circ}C$ cream containing 45% fat was completely destabilized. Destabilization of cream by freezing was also confirmed by electronmicroscopic studies made by Knoop and Wortman (1959). Lagoni and Kieler (1959) suggested that the fall in vapour pressure during freezing caused dehydration of colloids and was responsible for the destabilization of cream. Lagoni and Peters (1961) attributed the effect of freezing on the stability of fat

emulsion in frozen cream to the difference in the heat conductivity between water and fat. This difference can be minimized by quick freezing and thawing.

Effect of pasteurization on the fat stability in products to be frozen was investigated by Trout and Sheid (1943). They reported that cream which was pasteurized at 160°F for 15 minutes showed less destabilization upon freezing than cream which was pasteurized at 150°F for 30 minutes, or at 185°F for 5 minutes.

7. Heating and Drying

Radema (1953) in his investigation of cream pasteurization in buttermaking, came to the conclusion that the membranes of the cream fat globules undergo a change during pasteurization which causes a decrease in the fat content of buttermilk and an increase in the churning time. Lowenstein and Gould (1954) showed that when milk was heated to 82°C (180 F) for 15 minutes there was a loss of recoverable membrane material and that the loss of protein exceeded the loss of lipids. Jackson (1959) showed that the amount of membrane material recovered from homogenized milk heated to 175°F for 30 minutes was less than from batchs heated to 145° or 160°F. Apparently a milk heat treatment in the absence of violent agitation does not cause excessive losses of membrane material. However, high velocity heating systems from which air has not been excluded could be a factor in the destabil-

ization of the fat emulsion. Greenbank and Pallansch (1961) observed that the agitation which accompanied the concentration of milk in a single effect evaporator caused a migration of phospholipids into the skim milk phase.

Native lipo-proteins, as well as induced lipo-protein interactions, are dissociated by sharp freezing and dehydration. As such drying of milk or cream results in the partial destabilization of milk-fat emulsion. King (1954) stated that the fate of the fat globule membrane is deeply influenced by the processing methods and condition during storage.

8. Physico-Chemical and Biological factors

Physical methods of cream destabilization include exposure of cream to ultrasonic vibrations and washing of cream. A French patent (Capron & Julius, 1948) describes equipment using ultrasonic vibrations for aggregating the fat globules of cream into butter granules. A German patent (Kottenhahn, 1953) refers to a method and device for prechurning the cream.

The washing of cream causes a decrease in the phospholipid and protein content of the fat globule membrane. Rimpila and Palmer (1935) found that the natural creams with-stood washing with water up to 12 times. After the 12th washing the emulsion began to break, but a certain number of globules with their membrane intact persisted even after 24 washings.

Certain organic and inorganic compounds when added to

milk or milk products attack the membrane of the milk fat globules.' The action of chemical substances, sometimes accompanied by the heating of the mixture, is the basis for volumetric determination of butterfat in milk and milk products. Milkfat testing methods have been devised which make use of different wetting agents as demulsifiers. The BDI detergent test, elaborated by the Bureau of Dairy Industry, U.S.A. (Sager et al.(1951), Sager and Saunders 1952), uses an aqueous solution of non-ionic wetting agent. Stine et al.(1954) employed the BDI reagent to break the fat emulsion in milk and dairy products for obtaining fat for estimation of peroxide value. Patton (1952) and Stine and Patton (1951, 1952, 1953) used chemical reagents to produce butter oil. Patton (1952) stated that the effectiveness of the organic compounds in breaking the fat emulsions depends on their ability to penetrate and disperse the proteinaceous material of the fat globule membrane. Stine and Patton (1952) stated that certain surface-active agents can break the milkfat emulsion when added to cream at a level of 10% or less. King (1957) pointed out that certain surface-active agents added to the whole milk may bring to the surface separate or clumped fat globules or patches of destabilized fat; alternately they may be caused to sink. Alcohols in general can bring the fat globules to the surface of the milk much faster than mechanical disturbances, while glycerols are less active. Spans (Sorbitans) and Tweens (polyoxyethylenes), affect a sweeping or removal of the fat globule from the surface of the milk. The action of surface

active agents was accounted for by the fact that they are adsorbed on the surface of the fat globules and at the same time they spread out on the surface of the freshly formed fat droplets sweeping their surfaces clean of fat which had leaked out of the globules. The action of the alcohols was attributed to the fact that they compete for the polar side chains of the protein replacing the removed fat. It was also observed that alcohols increase the hydrophobic properties of the surface of the fat globules and this is considered as the first stage in demulsification.

Stone (1952) and Rowlands (1953) reported that certain bacteria e.g. Bacillus cereus and B. mycoides which produce a lecithin splitting enzyme lecithinase, may under certain conditions cause the fault of "broken" or bitty cream in raw and pasteurized milk.

9. The Influence of Preliminary Destabilization of Fat in Cream on the Quality of Butter.

The available information in the literature on the influence of preliminary destabilization of fat in cream on the subsequent quality of butter is very incomplete. Preliminary investigations on a prechurn carried out by the Cherry-Burrell Corporation and reported by Wiencreich (1965) indicated that the butter manufactured from destabilized cream was slightly firmer in body or Agienko (1966 a) stated that by regulating the extent of mechanical treatment on the high fat cream and the temperature of cooling, it was possible to produce butter with good structure and consistency, regardless

of the preliminary destabilization of the fat emulsion of high fat cream. Agienko (1966 b) studied the effect of preliminary destabilization of cream on the keeping quality of butter made from such cream. From his observations on such butter stored for 3 years he concluded that there was no effect on the quality of butter as regards plasma acidity, peroxide value, iodine value and score of the butter.

10. Methods of Measuring Destabilized Fat

Methods for quantitative measurement of destabilized fat in cream have not been used extensively. The presence of churned or destabilized fat in cream was reported on the basis of visual observation, although in certain cases, quantitative measurement of destabilized fat was made in frozen cream and ice-cream.

a. The Oiling-Off Method

The oiling-off method has been used to determine the destabilization of the fat emulsion of frozen milk and cream. Webb and Hall (1935) described this method as follows:
"9 grams of cream were weighed into 9-gram Babock test bottles and placed in the -17°C (1.4°F) room for 24 hours. The samples were thawed in a 40°C bath for 15 minutes, then whirled in a warm (40°C) Babcock tester for 30 minutes, removed and held in a cold box (15°C) overnight. The warming and whirling were repeated next day,

after which time the length of the column of clear fat was read in the usual manner. Holding the cream cold between whirlings was found necessary to give a clear fat column. Control tests were always run on the unfrozen samples which generally showed about 0.5 to 1.0 percent fat separation. These figures were subtracted from the readings obtained on the frozen samples."

This method was later applied by Bell and Sanders (1945, 1946) to measure the emulsion stability of the frozen cream. They modified the test by clarifying the fat column by leaving the Babcock bottles overnight in a warm room that was maintained at 10°C, instead of 15°C and no control tests were run on the unfrozen samples. Keeney and Josephson (1958) modified the procedure by using an 8% Babcock milk test bottle, centrifuging the sample for 10 minutes and reading the fat column after tempering in a 55 - 60°C water-bath. Overnight tempering of the samples was ommitted. With this procedure, two layers are formed in the neck of the test bottle. The top layer is clear butter oil, and below it a "cream - like" layer of partly destabilized milk fat is formed. One half of the cream-like layer is assumed to be destabilized when measurements are recorded.

b. The Turbidity Method

The procedure for the turbidity method, as applied by Keeney and Josephson (1958) to ice cream is as follows: A 1:500 dilution of the mix or the thawed ice cream is prepared

by weighing a 1 gram sample into a 50 ml volumetric flask. The weighed sample is diluted to the mark with distilled water, and 1 ml of the 1:50 dilution is transferred to a colorimeter tube and diluted with 9 ml of distilled water using a cream pipette. This 1:500 dilution is then centrifuged for 5 minutes at 1,000 r.p.m. and allowed to stand undisturbed for 10 minutes before reading the light transmission with a Klett-Summerson colorimeter fitted with a 500 μ light filter. Turbidity is recorded as Klett units. The degree of the fat emulsion stability is calculated as follows, using the turbidity of the mix to indicate 100 per cent stability:

$$\frac{\text{Turbidity of samples (Klett units)}}{\text{Turbidity of mix (Klett units)}} \times 100 = \begin{array}{l}\text{Degree of} \\ \text{Stability of} \\ \text{Fat emulsion}\end{array}$$

From the values obtained by this formula the percentage of destabilized fat is calculated by subtracting the values from 100. This method is based on the fact that the separation of fat due to destabilization causes an increase in light transmission through the sample and consequent decrease in the turbidity of the sample. The decrease in turbidity corresponds to the increase in the destabilization of fat.

c. <u>The Filtration Method</u>

Favstova and Vladavets (1955) reported a filtration method for measuring the destabilized fat in the high fat content cream used in the Alpha method of continuous buttermaking. The

method reported by the authors is as follows:

"A 5 gram sample is weighed into a glass test tube and kept in a water bath at 65°C for 5 minutes. Next, the heated sample is diluted 20 times with distilled water and kept in a cool water bath at 12°C or less till the fat becomes hard. The cooled diluted sample is then filtered using a No 1 glass filter to remove the destabilized (aggregated) portion of the fat from the filtrate. The rate or the degree of destabilization of fat in cream is calculated by using the following formula:

$$D = \frac{F - 20\ Ff}{F}$$

Where D = stability of the fat emulsion

F = original fat content of the cream

20 = the rate of dilution

Ff = fat content of the filtrate

4. <u>The Dilution and Separation Method</u>

This method was developed by Schulz *et al.* (1959) also for measuring destabilization in high fat content cream. The procedure is described by the authors as follows:

"10 grams of the product to be tested are added to 90 ml of tap water at 65°C and the mixture of the sample and water is kept in a water-bath at 65°C for 5 minutes. Next, the warm mixture is transferred to a separatory funnel. After 5 minutes, the lower portion is drained and its fat content is determined butyrometrically. The value obtained for the fat content of the lower portion multiplied

by 10 indicates the fat content of the cream phase. The term "fat in the cream phase" is to be understood as that cream fat dilutable with temperated water at 65°C without the fat being separated.

III. EXPERIMENTAL METHODS

A. PRELIMINARY INVESTIGATIONS

1. Method for Determining the Destabilized Fat in Cream

In the selection of a procedure for measuring the destabilized fat content of cream, the dilution and filtration method of Favstova and Vladavets (1955) and the dilution and separation method of Schulz *et al.*(1959) were compared. The glass filter used in the filtration method was a conical Hysil Brand, porosity I. The comparisons are recorded in Table I.

These results show that excepting in two cases the values for destabilized fat in cream obtained by filtration method were higher than obtained by separation method. This might have been caused by clogging of the filter and thus preventing the passage of some of the fat globules into the filtrate where they could be measured. Another disadvantage of the dilution and filtration method was that it required filtration under vacuum to speed up the filtration process. Also the samples had to be warmed up again to test the fat of the filtrate by the Babcock method. The dilution factor for the dilution and filtration method was 20 as compared to 10 of the dilution and separation method. Thus there was greater chance of an error in the former method. The standard error calculated from 10 replicates for the dilution and filtration method and dilution and separation method was $\pm$ 0.967 and $\pm$0.45 respectively. Because of these shortcomings of the dilution and filtration method, the dilution and separation method

Table 1. A comparison of methods used for testing destabilized fat in cream.

Sample no.	Fat in cream (%)	Destabilized fat (%)	
		Schulz *et al.* (1959)	Favstova and Vladavets (1955)
1	34.0	17.6	23.5
2	39.0	2.3	7.7
3	40.0	2.5	10.0
4	32.0	0.0	0.0
5	37.0	2.4	2.4
6	28.0	4.0	7.2

of Schulz et al.(1959) was adopted for subsequent work, with the modification that the Babcock method for testing fat was used instead of the Gerber method as specified in the original procedure. The following procedure was used in this investigation:

A 10 g sample of cream was weighed into a 150 ml beaker, diluted with 90 ml of tap water at 65°C and held in a water-bath at this temperature for 5 minutes. It was then introduced into a separatory funnel of 125 ml capacity. The lower portion was drained after 5 minutes and after cooling to 20°C its fat content was measured by the Babcock method. The obtained value multiplied by 10 (the dilution factor) represents the fat percentage in the cream phase of the sample.

Calculation of the extent of destabilization of fat in cream

If the fat content of the cream sample is 35% and it is diluted 1:10 and the bottom layer after separation found to test 3.3%, then the amount of destabilized fat in the cream is calculated as follows:

Butterfat content of the cream = 35%

Butterfat content of the bottom layer of the cream and water mixture = 3.3%

Fat in the cream phase = 3.3 X 10 = 33%

Destabilized fat in the cream = 35 - 33 = 2%

The destabilized fat content of the cream expressed as percent of the total fat = $\frac{2 \times 100}{35}$ = 5.7%

2. <u>Measurements of the Destabilization of Fat in Cream Received at the Local Creameries</u>

Measurements of the destabilization of fat in the cream of a considerable number of shippers to local creameries were made on summer as well as winter produced cream. In addition the destabilized fat content of a selected number of shippers was measured over the period of 5 weeks in summer to determine whether there was a similarity in the extent of the destabilization of the cream of any one producer over this period of time.

3. <u>The Effect of Initial Destabilization of Cream on the Churning Time of Cream</u> (laboratory scale experiments)

The effect of initial destabilization of fat in cream on the churning time was studied. A range in the percentages of destabilized fat in cream was obtained by mixing normal cream with the destabilized cream obtained from the Gold'n Flow process of buttermaking. The cream mixtures used were as follows:

100% normal cream.

75% normal cream + 25% destabilized cream.

50% normal cream + 50% destabilized cream.

25% normal cream + 75% destabilized cream.

After mixing the creams in the above proportions the percent of destabilized fat was determined.

Samples of each of these mixtures (700ml quantity) were churned with a Waring Blender and the time required for churning eg. the time when butter granules separated from the buttermilk, was recorded.

4. The Progress and Rate of Destabilization of Cream During the Conventional Churning Procedure.

The progress and rate of destabilization of fat in cream during buttermaking by the conventional method was determined. Samples of cream were removed from the churn at regular intervals of time and the percent of destabilized fat determined.

B. REDUCTION IN CHURNING TIME BY DESTABILIZATION OF CREAM

1. Processing of Cream

Special or number one grade farm separated cream was obtained from a local creamery. The cream was neutralized to a titable acidity of 0.1% with sesqui-carbonate neutralizer which was added to the cream when it reached a temperature of 80 - 90°F. The cream was pasteurized to 170°F and held at that temperature for 10 minutes in a holder pasteurizer (Cherry - Burrell Univat Model UA - 50 gallon capacity).

The cream for all churnings received a preliminary cooling to 90°F by circulation of tap water at 60 - 65°F. The method of cooling below 90°F varied as follows:

a. Slow cooling for overnight holding

When cream was held overnight for churning on the following day, it was pumped at 90°F into a Zero T - 20 vacuum bulk milk refrigerated tank, cooled slowly, and held at the required temperature.

b. Rapid cooling of cream for churning on the same day

Cream at 90°F was pumped through the chilled milk section of a HTST pasteurizer and cooled to 50 - 52°F. Further cooling, if

required, was carried out in the Zero T - 20 vacuum bulk milk refrigerated tank and the cream was churned as early as possible.

Since there was a rise of 6 - 8°F in the temperature of cream when it was passed through the destabilizing pumps, it was cooled and held at a temperature 7°F lower than the churning temperature. In the case of the portion of cream which was churned without passing it through the destabilizing pumps, the temperature was raised to churning temperature by running warm water (100-110°F) on the outside of the stainless steel churn.

2. <u>The Effects of Several Variables on the Extent of Destabilization of Fat in Cream</u>

The variables studied were:

I. Air pressure.

II. Product pressure.

III. Rate of flow of the metering pump.

The cream processed in the manner previously described was destabilized with the equipment shown in Figures 1 and 2 and the influence of these factors on the destabilization was determined.

3. <u>The Effect of Destabilization of Fat in Cream on the Churning Time</u>

a. <u>Destabilization of slowly cooled cream with one destabilizing pump</u>

Approximately 720 lbs of slowly cooled processed cream (as described earlier) was churned as follows:

One half of this batch of cream (Ca 360 lbs) was destabilized with the equipment shown in Figure I and churned in a Gosselin

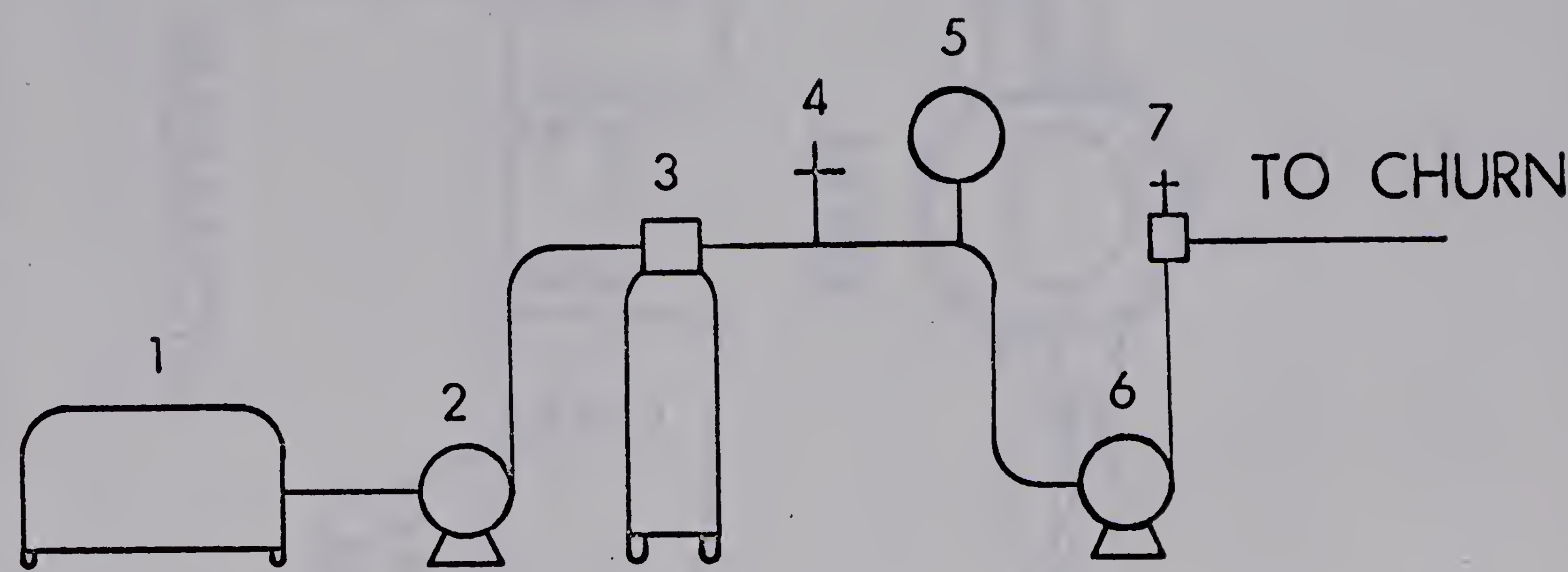

Figure 1 Equipment used for the mechanical destabilization of cream

1. Cream Vat
2. Centrifugal Pump
3. Metering Pump - Waukesha No 10
4. Air Supply
5. Sanitary Pressure Gauge
6. Destabilizing Pump Cherry-Burrell Flexflo Model VAH with Perforated Impeller*
7. Pressure Regulating Valve

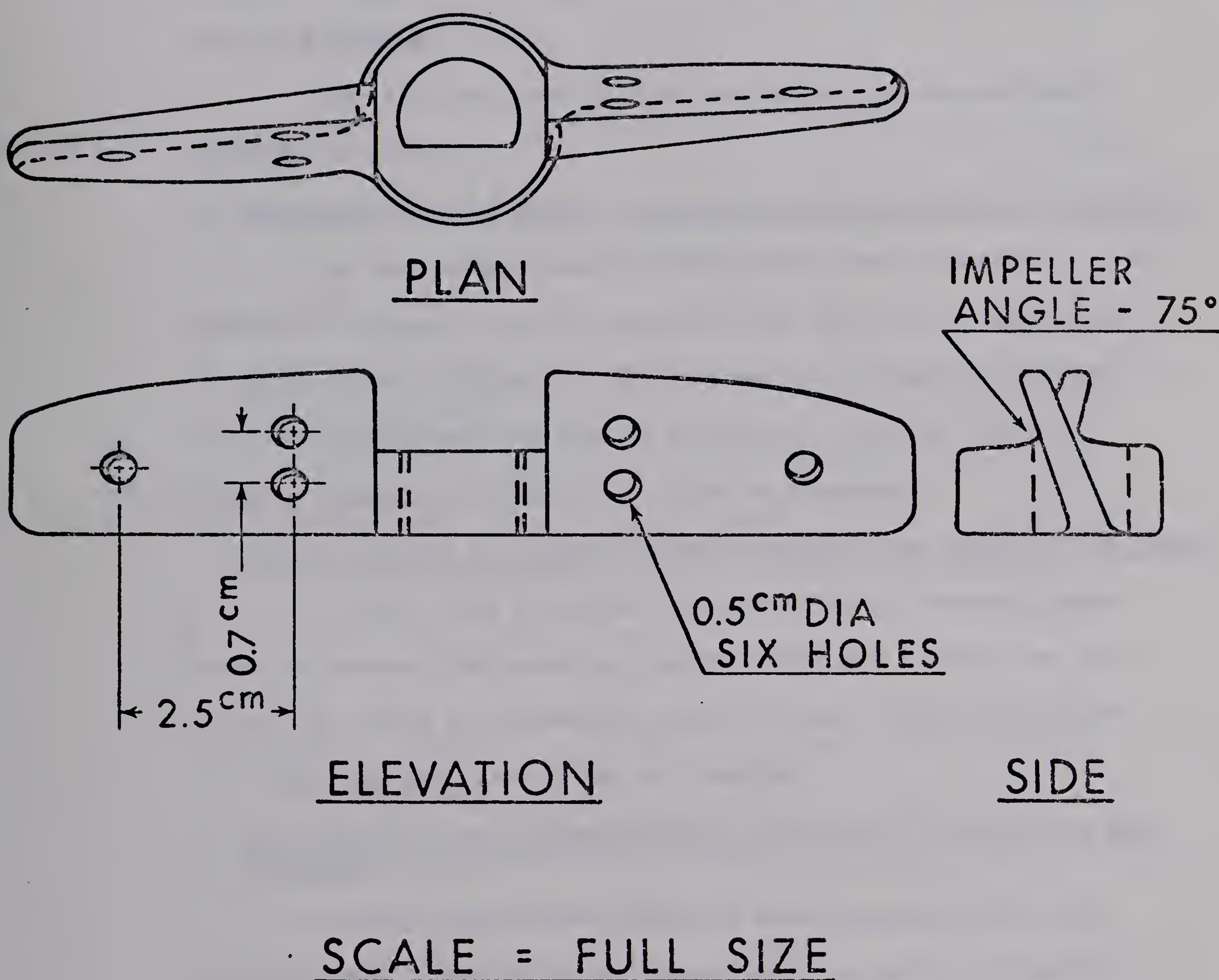

Figure 2 Impeller of the destabilizing pump

Stainless Steel drum type churn, supplied by J.A. Gosselin Co. Ltd., Drummondville, Que., Canada.

The other half of the cream was pumped into the churn, warmed to the same churning temperature as that of the destabilized cream and churned.

The time required to churn the normal and destabilized cream was recorded.

b. Destabilization of slowly cooled cream with two destabilizing pumps

In this case, cream was subjected to more intensive mechanical treatment with two destabilizing pumps in series instead of one as shown in Figure I. The processing of cream and quantity of cream churned were the same as in part a. The time required to churn normal and destabilized cream was recorded.

c. Destabilization of rapidly cooled cream with two destabilizing pumps

In this case cream was cooled rapidly to churning temperature and destabilized with two destabilizing pumps. This was done to achieve saving in the holding time of cream. The churning time for normal and processed cream was recorded.

d. The effect of the prechurned butter granules on the churning time of cream.

Cream (approximately 700 lbs) was processed by the slow cooling method. 350 lbs of this cream were churned in a Silkeborg UOH type Top churn. Buttermilk was drained when butter granules were approximately of pea size. The other half of the cream was pumped and churned along with the butter granules obtained from the previous churning. The effect of the presence of butter granules

on the churning time was recorded.

4. Savings in Working Time of Butter

Slowly cooled normal cream was churned and the time of working the butter recorded.

In a second set of experiments butter was manufactured by churning a batch of cream in the presence of butter granules obtained from the previous churning (as in 3d). Butter obtained from these two batches was worked together and the saving in working time calculated.

5. The Effect of Preliminary Destabilization of Cream on the Butterfat Test of Buttermilk

Butterfat tests of the buttermilk obtained from various churnings were carried out using the Mojonier method in order to determine whether destabilization of the cream prior to churning increased the loss of fat in churning.

6. Hardness of Butter as Affected by Preliminary Destabilization of Cream

Hardness measurements were made on the butter obtained from normal cream and cream which was destabilized with two pumps. Hardness was measured with the Kruisheer and den Herder disc penetrometer method as modified by deMan and Wood (1958 b).

C. THE EFFECT OF HOMOGENIZATION ON HIGH FAT CONTENT CREAM

High fat content cream (65 - 76%) was subjected to varying homogenizing pressures (1,000 - 3,000 p.s.i.) over a range of temper-

ature (140 - 165 °F). Since there were no facilities available in the department to obtain high fat cream, it was obtained from a local creamery and the following process was used to obtain it.

Plant separated cream (ca 35% fat) was subjected to heating by direct steam injection to a temperature of 190 - 195 °F. This cream was then reseparated through the separator, which was heated by running hot water through it for 10 - 15 minutes. The temperature of cream thus obtained varied from 170 - 175 °F. The high fat cream was transported to the departmental laboratory in an insulated container. The fat percent of the cream was adjusted with 30 - 35% cream, which was previously heated by direct steam injection. The homogenization was carried out using a single stage Gaulin Laboratory homogenizer. The destabilization of the fat in the cream was measured.

IV. RESULTS

A. PRELIMINARY INVESTIGATIONS

1. The Measurement of the Destabilization of Fat in Cream Received at the Local Creameries

Representative samples from the cream supplied by each shipper at the local creameries were obtained and tested for destabilized fat. Results obtained are given in Table 2A and Table 2B. The destabilized fat in cream ranged from 0 - 63% during the winter season and from 2 - 16% during the summer season with a majority of samples having an initial destabilized fat in the range of 0 - 10%. Figure 3 shows the percent distribution of samples in different ranges of destabilized fat. The samples taken from a bulk cream storage tank during summer months gave a test of 8 - 14% of destabilized fat over a period five weeks (Table 2B). These results show that almost all the samples received at the creameries had a certain amount of destabilized fat and that destabilization of fat in cream was higher in samples obtained during winter than those obtained during summer. No direct relationship of the titrable acidity of cream to percent destabilized fat in cream could be established on the basis of these samples. It appears that other factors e.g. agitation and/or freezing during storage and transportation of cream were more effective in causing the destabilization of fat in cream than the titrable acidity alone.

Table 2A. The percent destabilized fat in cream shipments* received at local creameries.

Sample no.	Fat in cream (%)	Titrable acidity	Destabilized fat in cream (%)
1	41.0	0.36	12.2
2	38.0	0.38	63.1
3	19.0	0.37	5.3
4	28.0	0.26	0
5	46.0	0.48	10.9
6	40.0	0.20	5.0
7	37.0	0.16	5.4
8	40.0	0.32	7.5
9	43.0	0.38	9.3
10	52.0	0.26	9.6
11	37.0	0.46	18.9
12	34.0	0.39	11.7
13	41.0	0.61	19.5
14	38.0	0.55	18.4
15	44.0	0.40	13.6
16	41.0	0.19	5.0
17	45.0	0.38	8.8
18	40.0	0.46	10.0
19	41.0	0.23	12.2
20	32.0	0.26	9.4

*Samples taken in March 1966.

Table 2A (cont'd). The percent destabilized fat in cream shipments* received at local creameries.

Sample no.	Fat in cream (%)	Titrable acidity	Destabilized fat in cream (%)
21	39.0	0.45	10.25
22	42.0	0.20	7.10
23	42.0	0.21	4.76
24	36.0	0.52	16.60
25	29.0	0.53	37.90
26	39.0	0.25	23.00
27	37.0	0.51	8.10
28	39.0	0.58	25.60
29	36.0	0.31	8.30
30	38.0	0.56	23.70
31	44.0	0.36	13.60
32	48.0	0.28	8.33
33	41.0	0.36	9.75
34	41.0	0.40	12.20
35	37.0	0.42	10.80
36	38.0	0.51	17.10
37	49.0	0.60	18.30
38	42.0	0.45	11.90
39	36.0	0.36	8.33
40	31.0	0.28	6.40

*Samples taken in March 1966.

Table 2B. The variations in the percent of destabilized fat in the cream of 14 shippers over a period of 5 weeks.

Shipper no.	Destabilized fat in cream (%)				
	22/7	29/7	5/8	12/8	19/8
1	13.0	12.0	10.0	14.0	16.0
2	2.0	2.5	3.0	7.0	3.0
3	5.0	-	3.0	7.5	8.0
4	5.0	5.5	4.0	8.0	-
5	3.0	7.5	5.0	5.0	7.0
6	13.5	3.0	7.5	5.0	5.0
7	13.5	6.0	8.0	3.0	7.5
8	7.0	5.0	6.5	4.5	4.0
9	3.0	7.0	5.0	6.0	6.0
10	8.0	10.0	13.0	10.0	-
11	6.0	5.0	8.0	7.0	10.0
12	4.0	-	3.0	4.0	5.0
13	3.0	3.0	6.0	7.0	5.0
14	2.0	5.0	4.0	8.0	3.0
Bulk cream storage tank	8.0	13.0	10.0	12.0	14.0

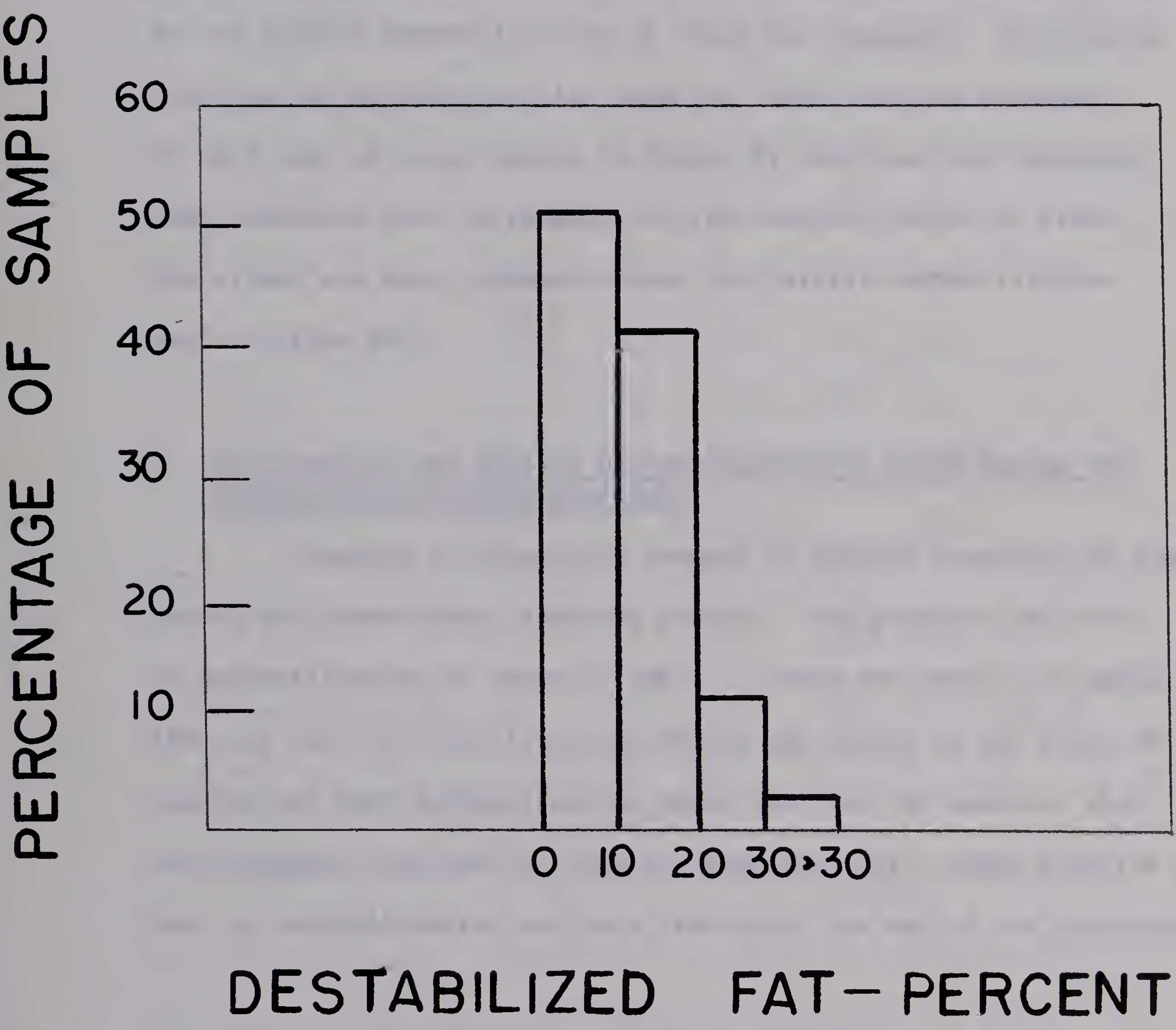

Figure 3 Distribution of samples on the basis of percent destabilized fat in cream shipments received at creameries during the winter season

2. The Effect of Initial Destabilization of Cream on the Churning Time of Cream (laboratory scale experiments)

The cream samples with different degrees of destabilization were churned with a Waring blender and the churning time as affected by the initial destabilization of cream was compared. The results based on the average churning time for three separate churnings of each type of cream (given in Figure 4) show that the churning time decreased with increasing initial destabilization of cream. The effect was more pronounced when the initial destabilization was more than 60%.

3. The Progress and Rate of Destabilization of Cream During the Conventional Churning Procedure

Samples of cream were removed at regular intervals of time during the conventional churning process. The progress and rate of destabilization is shown in Table 3. From the results it appears that the rate of destabilization of fat was faster in the first 20 minutes and that destabilization after the first 20 minutes, with one exception, was more or less the same (Ca 90%). After this the rate of destabilization was very slow until the end of the churning.

B. REDUCTION IN CHURNING TIME BY DESTABILIZATION OF CREAM

1. The Effects of Several Variables on the Extent of Destabilization of Fat in Cream

The processed cream was destabilized with the equipment shown in Figure I. The results in Table 4 show that increased air pressure which resulted in a greater volume of air being incorporated

Table 3. The progress of fat destabilization in cream during churning.

Time from start of churning (min) (Churning no)	Destabilized fat in cream (%)*					
	1	2	3	4	5	6
0	22.6	30.0	16.0	10.0	10.0	14.0
5	52.6	73.0	33.0	39.0	34.0	30.0
10	80.7	87.5	58.0	87.0	58.0	66.0
15	87.0	97.3	58.0	87.0	65.0	79.0
20	92.0	98.0	62.0	90.0	87.0	90.0
25	98.0	-	72.0	92.0	90.0	-
30	98.0	-	93.0	-	95.5	-
35	-	-	-	-	-	-
40	-	-	-	96.0	-	-
End of churning**	33.0	30.0	32.0	45.5	37.0	24.3

* Range of fat content in cream 36-39%.

** Time when butter granules separated from the buttermilk.

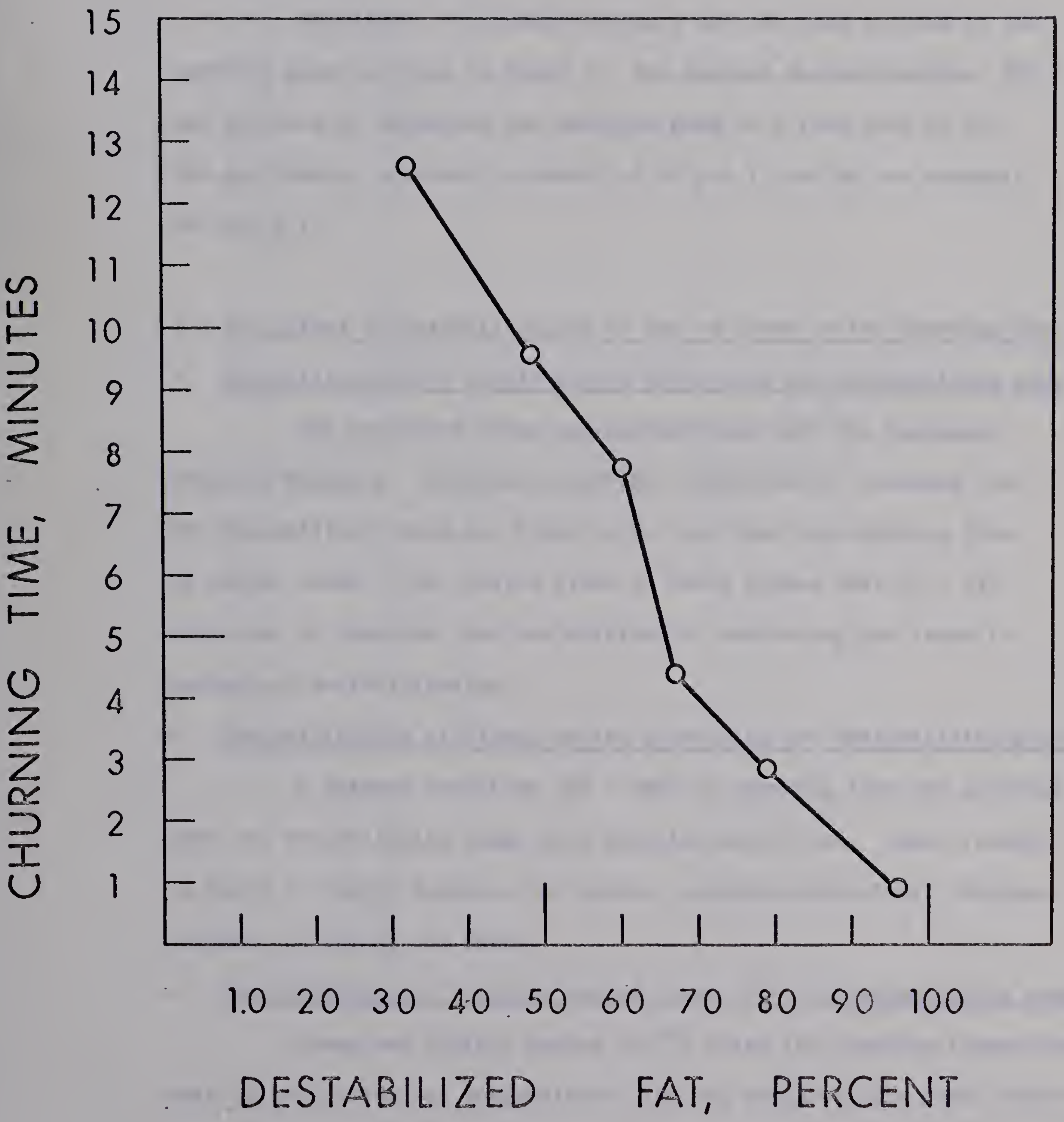

Figure 4 The churning time of cream as influenced by the initial destabilization of fat in cream

in the cream caused a greater destabilization. At an air pressure of zero p.s.i. the destabilization was 4% while at 30 p.s.i. 86% of the fat in cream was destabilized.

The effect of product pressure and the rate of flow of the metering pump is given in Table 5. The maximum destabilization, 85%, was achieved by adjusting the metering pump to a flow rate of 30 lbs per minute, a product pressure of 40 p.s.i. and an air pressure of 30 p.s.i.

2. The Effect of Destabilization of Fat in Cream on the Churning Time

a. Destabilization of slowly cooled cream with one destabilizing pump

The processed cream was destabilized with the equipment shown in Figure I. With one exception, (Trial no 4), churning time for destabilized cream was found to be less than the churning time of normal cream. The results given in Table 6 show that 22 - 73% reduction in churning time was obtained by subjecting the cream to mechanical destabilization.

b. Destabilization of slowly cooled cream with two destabilizing pumps

A greater reduction (40 - 86%) in churning time was achieved when two destabilizing pumps were used instead of one. These results in Table 7 clearly indicate the greater destabilizing effect obtained through the use of two pumps.

c. Destabilization of rapidly cooled cream with two destabilizing pumps

Cream was rapidly cooled to 7°F below the churning temperature. Half of this cream was destabilized with two destabilizing pumps before

m

Table 4. The influence of increasing air pressure on the destabilization of the fat in cream* processed with the destabilizing equipment.

Air pressure	Product pressure (psi)	Total pressure (psi)	Destabilized fat in cream (%)
0	0	0	4
15	40	55	21
25	30	55	27
30	25	55	86

* Fat content of cream = 36%.

Table 5. The effect of product pressures and rates of cream flow on the extent of destabilization of fat in cream processed with the destabilizing equipment.

Rate of flow of the pump (lbs/min)	Air pressure (psi)	Product pressure (psi)	Destabilized fat in cream	
			Trial I*	Trial II**
30	30	20	81	76
30	30	30	83	65
30	30	40	85	78
36	30	40	64	56
36	30	30	45	-
43	30	30	64	62
43	30	40	67	67

Fat content of cream = 36%*
37%**

Initial destabilized fat = 5.5%*
10%**

Table 6. A comparison of churning times of slowly cooled creams before and after mechanical destabilization.

Trial no.	Fat in cream (%)	Destab. fat in cream (%)		Churning temperature of		Churning time (min)		Reduction in churning time due to mechanical destabilization (%)
		Before destab.	After destab.	Normal* cream	Destab. cream	Normal* cream	Destab. cream	
1	40.0	28.0	78.0	54	56	65.0	23.0	64.6
2	36.0	30.0	86.0	55	56	75.0	20.50	72.7
3	38.0	9.0	79.0	54	54	19.0	6.50	65.7
4	39.0	10.0	87.0	53	54	45.5	46.25	-
5	36.0	11.0	80.0	55	56	37.0	23.25	37.2
6	37.0	15.0	90.0	56	57	23.5	18.30	22.2

* Cream which has not been subjected to mechanical destabilization.

churning while the other half was churned without any mechanical destabilization. The results in Table 8 show that a reduction of 59 - 89% in churning time was obtained. Also a further saving in processing time equivalent to the time required for holding the cream overnight was achieved.

d. <u>The effect of the prechurned butter granules on the churning time of cream</u>

Cream was churned in the presence of butter granules obtained by churning half the quantity of the same batch of cream. The results are shown in Table 9. The presence of butter granules in the churn did not result in any appreciable reduction in the churning time.

3. <u>Savings in Working Time of Butter</u>

Comparisons were made of the time required for working butter made from one lot of cream and the butter made from two lots of cream which were worked together. A considerable saving in working time was obtained and these results are given in Table 10.

4. <u>The Effect of Preliminary Destabilization of Cream on the Butter-fat Test of Buttermilk</u>

Butterfattests were carried out on buttermilk samples obtained from all the churnings. The results reported in Table 11 show that the buttermilk samples obtained from churning cream which was subjected to mechanical destabilization gave a slightly lower test. On the otherhand buttermilk samples obtained from churning cream in the presence of prechurned butter granules gave higher

butterfat tests.

5. Hardness of Butter as Affected by Preliminary Destabilization of Cream

Hardness measurements were made on butter manufactured from normal cream and destabilized cream. The average values for the hardness of butter samples obtained from churning normal cream and destabilized cream were 6.74Kg/4 cm^2 and 6.70Kg/4 cm^2 respectively (Table 12). These results show that the preliminary destabilization of cream did not affect the hardness of butter.

C. THE EFFECT OF HOMOGENIZATION ON HIGH FAT CONTENT CREAM

Homogenization of high fat content cream resulted in its destabilization. The results are shown in Tables 13 - 16 and Figures 5 - 7 inclusive. Higher homogenizing pressures (2,000 to 3,000 p.s.i.) were more effective in destabilizing cream than pressures below 2,000 p.s.i. Cream with a fat content of 76% had a greater degree of destabilization than creams with 65 or 70% fat. A temperature of 165^{o}F was more effective in destabilization of cream than temperatures of 140 or 150^{o}F. The maximum destabilization achieved was 88.5% in cream having a fat content of 76%, a temperature of 165^{o}F and a homogenizing pressure of 3,000 p.s.i.

Table 7. A comparison of churning times of slowly cooled creams before and after mechanical destabilization using two destabilizing pumps.

Trial no.	Fat in cream (%)	Destab. fat in cream (%)		Churning temperature (°F)		Churning time (min)		Reduction in churning time due to mechanical destabilization (%)
		Before destab.	After destab.	Normal cream	Destab. cream	Normal cream	Destab. cream	
1	37.0	10.0	95.0	58	58	28.5	4.75	83.3
2	38.0	8.0	95.5	55	55	23.3	3.25	86.1
3	37.5	10.0	92.0	53	53	48.0	24.00	50.0
4	37.0	4.0	73.0	56	56	30.3	18.20	39.3

Table 8. A comparison of churning times of rapidly cooled creams before and after mechanical destabilization using two destabilizing pumps.

Trial no.	Fat in cream (%)	Destab. fat in cream (%)		Churning temperature (°F)		Churning time (min)		Reduction in churning time due to mechanical destabilization (%)
		Before destab.	After destab.	Normal cream	Destab. cream	Normal cream	Destab. cream	
1	35.0	13.0	98.0	50	50	25.80	2.8	89.2
2	37.0	8.0	92.0	49	50	38.80	13.0	66.5
3	38.0	5.3	74.8	50	50	36.75	15.0	59.2
4	35.0	20.0	99.0	52	52	18.80	2.01	89.3

Table 9. The influence on the churning time of cream churned in the presence of the granules from a previous churning.

Trial no.	Fat in cream (%)	Churning temperature (°F)	Churning time (min)	
			First churning	Second* churning
1	38.0	45	25.5	24.5
2	35.0	44	55.1	50.9
3	35.0	45	24.2	20.5
4	36.0	45	38.2	32.8
5	36.0	45	22.5	19.4

* Cream churned in the presence of butter granules from the first churning.

Table 10. A study of the working time for butter when two lots of butter were worked together.

Trial no.	Fat in cream (%)	Churning temperature (°F)	Churning time (min)		Working** time (min)	
			First churning	Second* churning	One lot	Two lots together
1	41.0	45	43	-	31	-
2	40.0	45	42	-	29	-
3	37.0	46	41	37	-	34
4	38.0	46	38	37	-	29
5	38.0	46	39	36	-	33

* Cream churned in the presence of butter granules from the first churning.

** Working time includes time required for carrying out first moisture test on butter.

Table 11. The influence of mechanical destabilization of cream on fat test of butter milk.

Trial no.	Fat test of butter milk (%)							
	I		II		III		IV	
	Normal cream	Destab. cream	Normal cream	Destab. cream	Normal cream	Destab. cream	Normal cream	Destab. cream
1	0.79	0.74	0.69	0.65	0.62	0.75	0.61	0.65
2	0.94	0.89	0.85	0.73	0.72	0.65	0.73	0.82
3	1.28	1.26	0.68	0.65	0.74	0.67	0.68	0.72
4	0.90	0.79	0.73	0.76	0.66	0.69	0.71	0.68
5	0.61	0.61	-	-	-	-	0.59	0.68
6	1.20	1.41	-	-	-	-	-	-
Average	0.953	0.90	0.737	0.697	0.685	0.69	0.66	0.71

I. Butter milk samples obtained from churnings reported in Table 6.
II. Butter milk samples obtained from churnings reported in Table 7.
III. Butter milk samples obtained from churnings reported in Table 8.
IV. Butter milk samples obtained from churnings reported in Table 9.

Table 12. Hardness measurements on butter* made before and after mechanical destabilization of cream.

Sample no.	Hardness measurements ($kg/4\ cm^2$)	
	Normal cream butter	Destabilized cream butter
1	5.75	5.40
2	6.60	6.80
3	7.90	7.80
4	6.70	6.80
Average	6.74	6.70

* Butter samples obtained from churnings reported in Table 8.

Table 13. The influence of homogenizing pressure on the destabilization of high fat content cream. (Temperature 140°F).

Fat in cream (%)	76.0		70.0		65.0	
Homogenizing pressure (p.s.i.)	Destabilized fat* in cream after homogenization (%).					
	I	II	I	II	I	II
1,000	9.20	10.0	10.0	12.5	4.6	4.0
1,500	15.0	16.0	13.0	15.0	7.7	9.5
2,000	51.3	48.5	24.3	21.0	10.7	11.0
2,500	70.9	74.0	28.6	33.0	15.4	13.5
3,000	83.0	80.0	31.4	35.0	20.0	18.0

* Values I & II were obtained by homogenizing two different samples of cream.

Table 14. The influence of homogenizing pressure on the destabilization of high fat content cream. (Temperature 150°F).

Fat in cream (%)	76.0		70.0		65.0	
Homogenizing pressure (p.s.i.)	Destabilized fat* in cream after homogenization (%).					
	I	II	I	II	I	II
1,000	10.5	14.0	10.0	8.0	7.7	6.0
1,500	15.8	14.0	17.0	12.5	15.3	6.0
2,000	54.0	58.5	31.4	28.0	15.3	14.0
2,500	73.7	77.0	44.3	49.5	18.5	15.8
3,000	84.2	82.0	45.7	54.0	23.0	18.0

* Values I & II were obtained by homogenizing two different samples of cream.

Table 15. The influence of homogenizing pressure on the destabilization of high fat content cream. (Temperature 160°F).

Fat in cream (%)	76.0		70.0		65.0	
Homogenizing pressure (p.s.i.)	Destabilized fat* in cream after homogenization (%).					
	I	II	I	II	I	II
1,000	59.0	50.0	14.0	11.4	8.0	5.0
1,500	75.0	71.1	30.0	28.5	9.2	6.1
2,000	78.0	77.0	61.5	48.0	12.3	13.8
2,500	82.0	80.2	70.0	67.1	27.0	31.0
3,000	87.0	83.5	76.0	77.0	45.0	41.0

* Values I & II were obtained by homogenizing two different samples of cream.

Table 16. The influence of homogenizing pressure on the destabilization of high fat content cream. (Temperature 165°F).

Fat in cream (%)	76.0		70.0		65.0	
Homogenizing pressure (p.s.i.)	Destabilized fat* in cream after homogenization (%).					
	I	II	I	II	I	II
1,000	55.3	58.5	7.0	13.0	4.6	6.0
1,500	64.5	69.0	27.0	38.0	4.6	8.5
2,000	77.6	82.0	58.6	60.0	28.0	23.0
2,500	83.5	84.0	77.1	72.5	33.0	31.0
3,000	85.5	88.5	78.5	76.0	55.0	49.0

* Values I & II were obtained by homogenizing two different samples of cream.

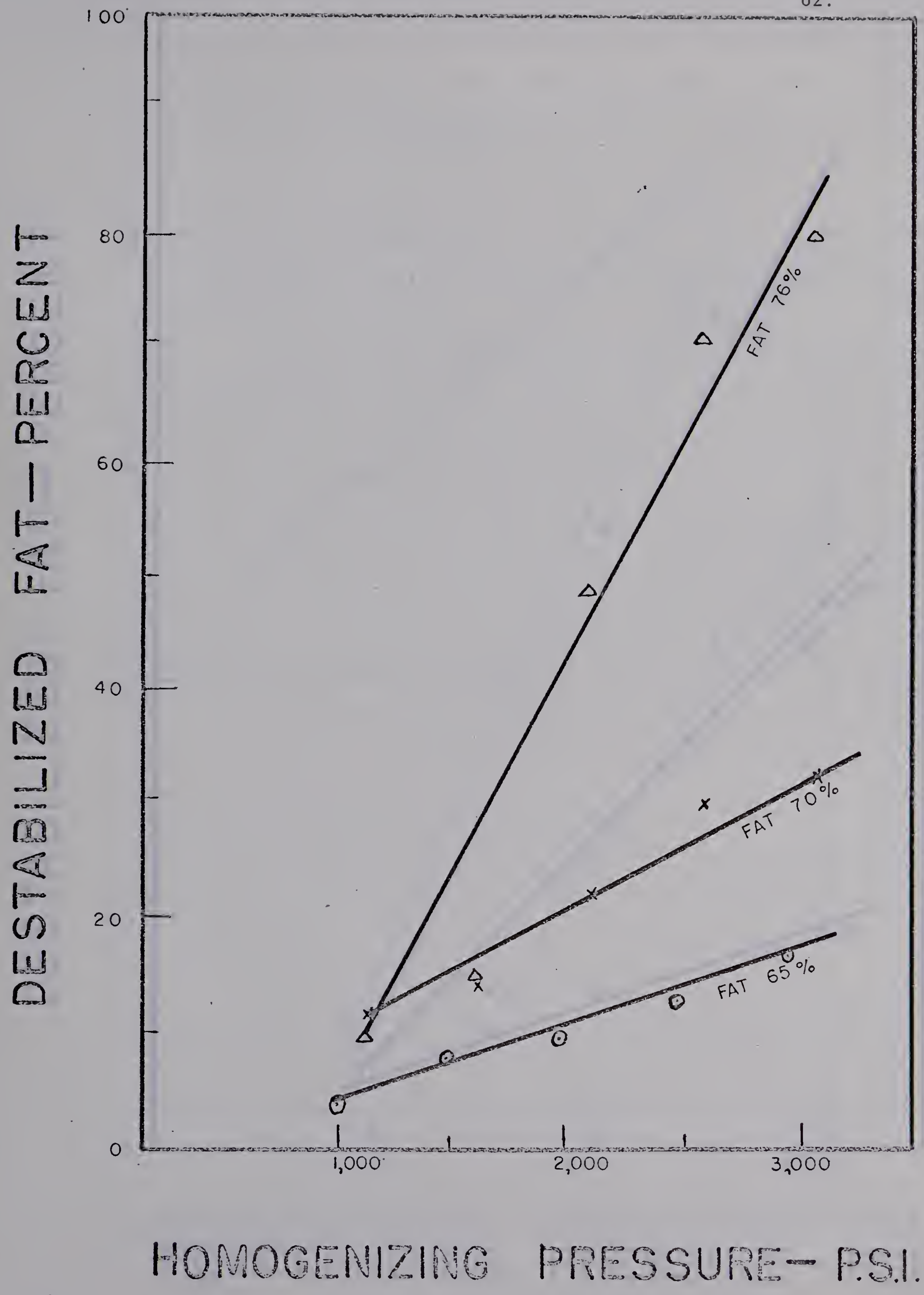

Figure 5 The relationship between the fat content and the percent destabilized fat in cream as influenced by the homogenizing pressure. (Cream Temperature 140°F)

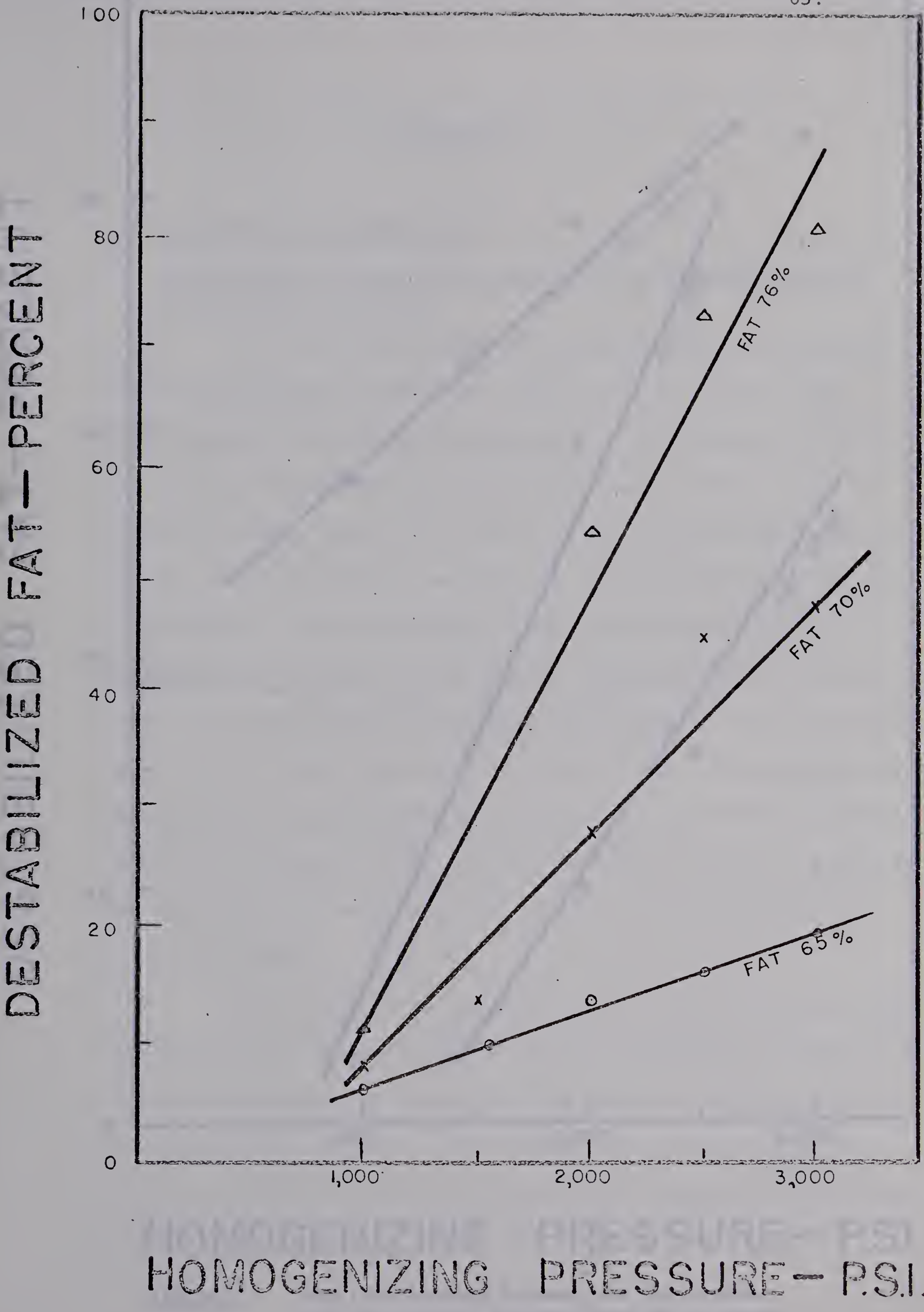

Figure 6 The relationship between the fat content and the percent destabilized fat in cream as influenced by the homogenizing pressure. (Cream Temperature 150°F)

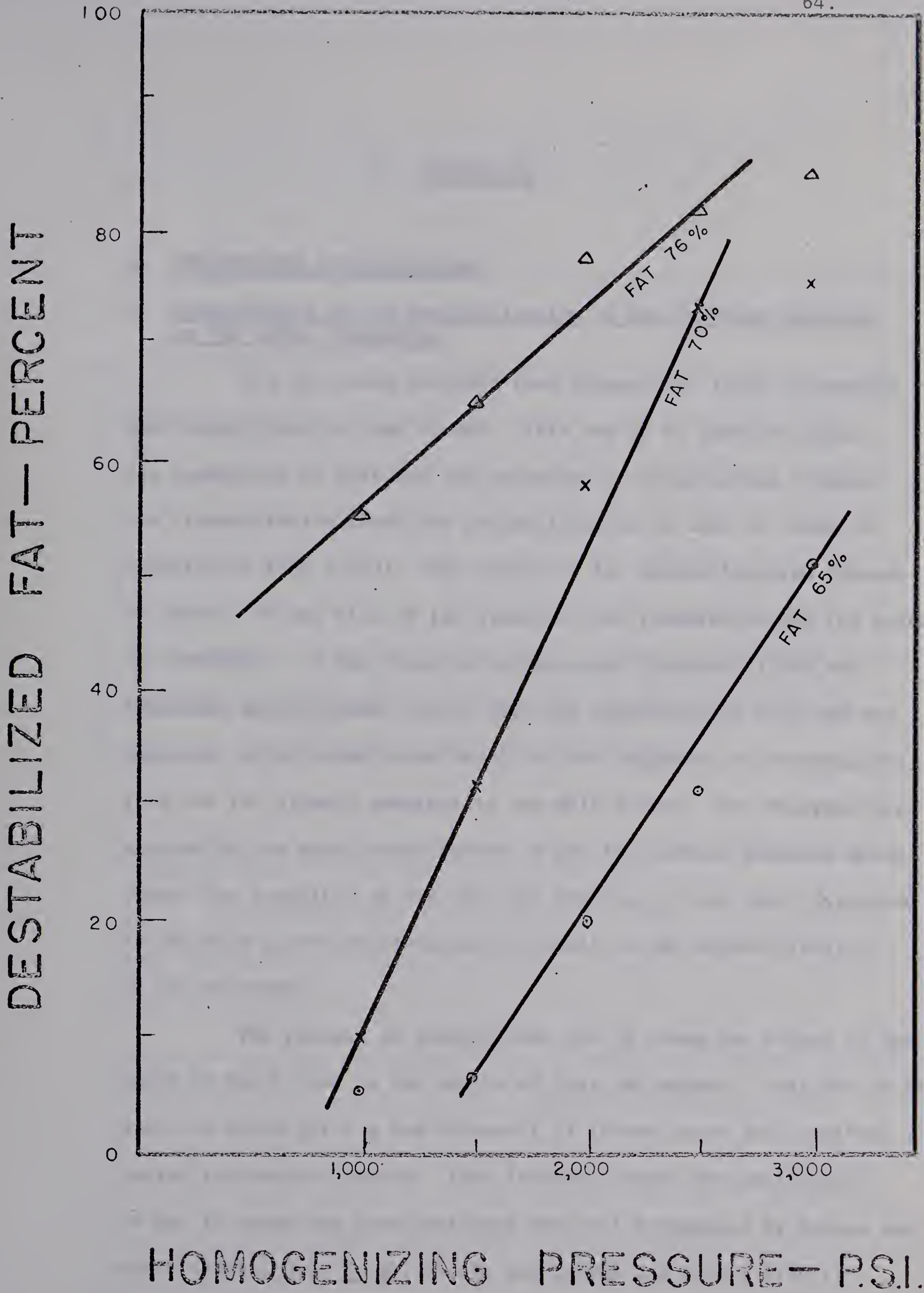

Figure 7 The relationship between the fat content and the percent destabilized fat in cream as influenced by the homogenizing pressure. (Cream Temperature 165°F)

V. DISCUSSION

A. PRELIMINARY INVESTIGATIONS

1. Measurements of the Destabilization of Fat in Cream Received at the Local Creameries

All the cream received from shippers at local creameries was destabilized to some extent. This was to be expected since the separation of milk and the agitation of cream during storage and transportation cause the destabilization of milk or cream as reported by King (1953). The extent of fat destabilization depends of course, on the size of fat globules, the temperature and the extent of treatment. It was reported by Koops and Tarassuk (1959) and Greenbank and Pallansch (1961) that the separation of milk and the agitation of milk and cream result in the migration of phosphatides from the fat globule membrane to the milk plasma. The phosphatides are one of the major constituents of the fat globule membrane which causes the stability of the milk fat emulsion. Thus their migration to the milk plasma would naturally result in the destabilization of fat in cream.

The percent of destabilized fat in cream was higher in the month of March than in the months of July and August. This was to be expected since quite a few shipments of frozen cream are received during the month of March. That freezing causes destabilization of fat in cream has been confirmed and well documented by Rochow and Mason (1936), Cole *et al*. (1959) and Lagoni and Peters (1961).

According to these authors, the various factors which cause the destabilization of fat in cream due to freezing are:

(a) Slow rate of freezing,

(b) fluctuations in temperature of storage after freezing,

(c) high fat content of cream.

The cream received at the creamery was frozen because of low atmospheric temperatures prevailing during storage and transportation. Since cream is stored and carried in cans or bulk, the process of freezing could not be rapid. The effect of acidity and fat content of cream could not be determined because the effect of freezing overshadowed the effect of these factors. Thus the separation of milk, agitation of cream during storage and transportation, and freezing and thawing of cream during winter months all contributed to the destabilization found in the fat of cream received at the creameries.

2. <u>The Effect of Initial Destabilization of Cream on the Churning Time of Cream</u> (laboratory scale experiments)

The churning time of cream samples churned with the Waring blender decreased with increasing initial destabilization of cream. When cream is churned with the Waring blender, the separation of butter granules from the buttermilk is affected by the almost complete destabilization of cream emulsion, caused by intense mechanical agitation and incorporation of air into the cream. Thus, with any one batch of cream the higher the initial destabilization of cream, the shorter the time required to churn the cream to almost complete destabilization.

3. <u>The Progress and Rate of Destabilization of Cream During the Conventional Churning Procedure</u>

The destabilization of fat in cream increases from the start of the churning process (Table 3). These findings corroborate the observation of King (1951, 1952) that destabilization of fat in milk or cream is dependent on the intensity and duration of mechanical action. It was also observed that the rate of destabilization of fat was very fast in the begining. This is explained by the observations reported by King (1953) that the volume of air incorporated into cream rises rapidly in the begining causing an extension of the air-plasma interface. A large number of the fat globules collect on this interface exposing unprotected fat surfaces to the air and spreading a thin layer of liquid fat over the surfaces of the air bubbles. This liquid fat acts as a cementing material between the fat globules resulting in the formation of clumps and the agglomeration of the clumps to form butter granules. Thus the rapid incorporation of air in the begining explains the rapid rate of fat destabilization during initial stages of churning. The rate of destabilization of fat after 20 minutes of churning slows down considerably because most of the fat globules have already clumped together. There is also a decrease in the volume of air incorporated. The remainder of the time, until the breaking stage is reached, is needed for the clumps to grow to butter granule size.

B. REDUCTION IN CHURNING TIME BY DESTABILIZATION OF CREAM

1. The Effects of Several Variables on the Extent of Destabilization of Fat in Cream

The variables which affected the extent of destabilization were:

I. Air pressure

II. Product pressure

III. Rate of flow of the metering pump.

Variation in the air pressure affected the rate and volume of the air incorporated into the cream when it is processed in the destabilizing equipment. Thus when a higher pressure of air was used (Table 4), higher percentages of destabilized fat in cream were obtained. This is explained by the preceeding discussion on the destabilization that occurs during conventional churning.

Increasing the product pressure and lowering the rate of flow of the metering pump resulted in the retention of cream in the destabilizing pump chamber for a longer time. Thus the cream was subjected to a greater duration of mechanical action and this caused greater destabilization of fat.

2. The Effect of Destabilization of Fat in Cream on the Churning Time

The cream destabilized by using the equipment shown in Figure I required less time for churning than the cream which was not subjected to destabilization (Table 6). An initial destabilization of 78 - 90% was obtained by using the destabilizing equipment. In Table 3 it was observed that this extent of destabilization was achieved in 10 - 20

minutes of churning. Taking 35 minutes as the average churning time, a reduction of 28 - 71% of the churning time was expected by using the destabilizing equipment. This accounts for 22 - 73% of the reduction in churning time reported in Table 6.

Reduction in churning time increased when two destabilizing pumps were employed instead of one. The resultant destabilization of fat in cream was more than 90%. In Trial no 4 and Trial no 3 of Tables 7 and 8, the percent of destabilized fat achieved was only 73.0 and 74.8 respectively. This reduced destabilization is accounted for by a reduced mechanical treatment of the cream caused by difficulties experienced in adjusting the destabilizing equipment. The introduction of two destabilizing pumps in the destabilization equipment reduced the churning time by 50 - 86% of the normal.

A similar reduction in churning time was obtained when the cream was destabilized without holding it overnight for partial crystallization of the liquid fat of the fat globules. This was achieved by cooling the cream to a lower temperature (approximately 7 - 8°F lower than the churning temperature) and allowing the rapid crystallization of fat, thereby establishing an optimum ratio between the crystalline and the liquid fat of the fat globules. When this cream was subjected to mechanical treatment there was a rise of 7 - 8°F; thus, cream at the right churning temperature was obtained.

When a batch of cream was churned in the presence of butter granules from a previous churning there was no appreciable saving

in the churning time. A slight reduction in the churning time caused may be due to these granules supplying a part of the liquid fat as the cementing material, and thereby accelerating the clumping of the fat globules to some extent.

3. Savings in Working Time of Butter

The working time for two batches of butter which were worked together was the same as for one batch. The working process involves the kneading of butter granules together to form a pliable mass. Thus as long as there is sufficient space for the butter granules to be kneaded and compressed due to gravity, the working of butter is quite efficient. However, it must be borne in mind that the amount of butter that can be worked in the churn will depend on the capacity of the electric motor and the strength of the churn. In order to take advantage of the saving of time that is possible by working two churnings of butter together, the working capacity and strength of the churn barrel, as well as the capacity of the electric motor must be taken into consideration.

4. The Effect of Preliminary Destabilization of Cream on the Butterfat Test of Buttermilk

Butterfat tests were carried out on the buttermilk obtained from all the churnings. The buttermilk obtained from churning cream which was subjected to mechanical destabilization gave a slightly

lower test than the buttermilk obtained from churning normal cream (Table 11). King (1953) reported that the following forms of fat in buttermilk may be discerned:

(i) Fat globules derived from the original cream which has escaped contact with the air bubbles,

(ii) Fragments of fat globules, of group of globules and of butter granules,

(iii) Fat in the colloidal state,

(iv) Fat-like substances (phospholipids etc).

In the mechanical destabilization of cream with the equipment shown in Figure I, air under pressure of 30 p.s.i. was incorporated into cream which was also subjected to a product pressure of 40 p.s.i. Thus there was a reduced opportunity for the fat globules to escape aggregation on the air phase surfaces and pass into the buttermilk. This might have caused a slightly lower fat test in the buttermilk samples obtained from churning the mechanically destabilized cream.

On the other hand, when cream was churned in the presence of butter granules from the previous churning, the buttermilk gave a higher butterfat test. This might have been caused by partial working of the butter granules during the second churning. The working of butter granules results in an increase in the liquid fat, a part of which might have escaped in the buttermilk from the second churning.

5. Hardness of Butter as Affected by Preliminary Destabilization of Cream

Hardness measurements were made on the butter obtained from

churning normal cream and cream which was subjected to mechanical destabilization. There was no appreciable difference in the hardness values. Hardness of butter depends largely on the proportion of solid fat and liquid fat. Since the temperature treatment received by both types of cream eg. normal as well as cream subjected to mechanical destabilization was the same, it may be assumed that they had the same proportion of liquid and crystalline fat and hence approximately the same degree of hardness.

C. THE EFFECT OF HOMOGENIZATION ON HIGH FAT CONTENT CREAM

The homogenization of high fat content cream varied in its effect on the destabilization of fat. The variables which affected the extent of destabilization were:

i Fat content of cream

ii Homogenizing pressure

iii Temperature of cream

The influence of these variables is shown in Figure 5 - 7 inclusive. At all the temperatures studied (140 - 165°F), increases in the homogenization pressure resulted in a higher degree of destabilization, the effect being more pronounced at a fat content of 76% than 65 or 70%. This is explained on the basis of observations made by Sommer (1946) that at a fat content higher than 74.04%, the fat globules in cream are tightly packed and deformed. The deformation of the fat globules stretches the fat globule membranes and makes them more succeptible to destabilization. The homogenization of cream accelrated the process of destabilization.

At a cream temperature of 165°F, there was a higher degree of destabilization in cream than at a temperature of 140 or 150°F. At this temperature, homogenizing pressures of 1,500 p.s.i. and above were more effective in destabilizing the cream emulsions than lower temperatures. A high temperature of cream (165°F) apparently caused the denaturation of fat globule membrane proteins which consequently lost their protective influence in stabilizing the cream emulsion. This resulted in a higher degree of destabilization of cream. At a homogenizing pressure of 3,000 p.s.i. and a fat content of 76%, the degree of destabilization was approximately the same at all temperatures. Apparently at a fat content of 76%, the destabilization due to distortion of fat globules over shadowed the destabilizing effect of high temperature.

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